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## APPENDICES

### Appendix A Density of Dense and Voided Films by Gas Pycnometer

-Cell size: small

-Target Pressure: 17 psi

-V added – Small: 12.4101 cc

-Maximum Runs: 20

-V cell: 20.8840 cc

-Number of Runs Averaged: 10

#### a) Dense Films

**Table A1** Tabular data density analysis of HDPE film

Run	Volume (cc)	Density (g/cc)
1	1.1350	0.9505
2	1.1344	0.9510
3	1.1343	0.9511
4	1.1358	0.9498
5	1.1364	0.9493
6	1.1366	0.9492
7	1.1370	0.9488
8	1.1375	0.9484
9	1.1367	0.9491
10	1.1363	0.9494
11	1.1362	0.9495
12	1.1368	0.9490
13	1.1371	0.9487
14	1.1378	0.9482
15	1.1369	0.9489
16	1.1363	0.9494
17	1.1357	0.9499
18	1.1364	0.9493
19	1.1362	0.9495
20	1.1369	0.9489
Average	1.1366	0.9491

**Table A2** Tabular data density analysis of PP film

Run	Volume (cc)	Density (g/cc)
1	1.1646	0.8989
2	1.1652	0.8984
3	1.1654	0.8982
4	1.1638	0.8995
5	1.1643	0.8991
6	1.1645	0.8989
7	1.1659	0.8978
8	1.1662	0.8976
9	1.1663	0.8975
10	1.1697	0.8949
11	1.1691	0.8954
12	1.1666	0.8973
13	1.1691	0.8954
14	1.1685	0.8959
15	1.1682	0.8961
16	1.1691	0.8954
17	1.1672	0.8968
18	1.1662	0.8976
19	1.1680	0.8962
20	1.1674	0.8967
<b>Average</b>	<b>1.1679</b>	<b>0.8963</b>

**b) Voided Films****Table A3** Tabular data density analysis of HDPE of 0.5 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.2996	0.8111
2	1.2975	0.8124
3	1.2935	0.8149
4	1.2962	0.8132
5	1.2986	0.8117
6	1.3018	0.8097
7	1.2992	0.8114
8	1.2956	0.8136
9	1.2957	0.8136
10	1.2981	0.8120
11	1.2982	0.8120
12	1.2976	0.8124
13	1.2970	0.8127
14	1.2969	0.8128
15	1.2986	0.8117
16	1.2979	0.8122
17	1.2984	0.8118
18	1.2975	0.8124
19	1.2970	0.8127
20	1.2988	0.8116
<b>Average</b>	<b>1.2978</b>	<b>0.8122</b>



**Table A4** Tabular data density analysis of HDPE of 1 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.3315	0.8067
2	1.3326	0.8061
3	1.3313	0.8069
4	1.3328	0.8060
5	1.3327	0.8061
6	1.3311	0.8070
7	1.3330	0.8059
8	1.3335	0.8055
9	1.3343	0.8051
10	1.3322	0.8064
11	1.3325	0.8061
12	1.3319	0.8065
13	1.3337	0.8054
14	1.3329	0.8059
15	1.3326	0.8061
16	1.3347	0.8048
17	1.3327	0.8060
18	1.3328	0.8060
19	1.3330	0.8058
20	1.3328	0.8060
<b>Average</b>	<b>1.3330</b>	<b>0.8059</b>

**Table A5** Tabular data density analysis of HDPE of 1.5 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.4817	0.7378
2	1.4834	0.7369
3	1.4800	0.7387
4	1.4809	0.7382
5	1.4799	0.7387
6	1.4809	0.7382
7	1.4817	0.7378
8	1.4812	0.7380
9	1.4795	0.7389
10	1.4806	0.7384
11	1.4797	0.7388
12	1.4803	0.7385
13	1.4801	0.7386
14	1.4814	0.7380
15	1.4814	0.7380
16	1.4807	0.7383
17	1.4813	0.7380
18	1.4802	0.7385
19	1.4826	0.7374
20	1.4802	0.7386
<b>Average</b>	<b>1.4808</b>	<b>0.7383</b>

**Table A6** Tabular data density analysis of HDPE of 2 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.4734	0.7341
2	1.4745	0.7335
3	1.4719	0.7348
4	1.4722	0.7347
5	1.4715	0.7350
6	1.4734	0.7341
7	1.4728	0.7344
8	1.4719	0.7348
9	1.4727	0.7344
10	1.4733	0.7341
11	1.4735	0.7340
12	1.4747	0.7335
13	1.4749	0.7333
14	1.4730	0.7343
15	1.4727	0.7344
16	1.4732	0.7342
17	1.4733	0.7341
18	1.4731	0.7343
19	1.4727	0.7344
20	1.4737	0.7339
<b>Average</b>	<b>1.4735</b>	<b>0.7341</b>

**Table A7** Tabular data density analysis of PP of 0.5 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.3353	0.7804
2	1.3366	0.7797
3	1.3360	0.7800
4	1.3366	0.7796
5	1.3386	0.7785
6	1.3367	0.7796
7	1.3361	0.7800
8	1.3378	0.7790
9	1.3371	0.7794
10	1.3370	0.7794
11	1.3359	0.7801
12	1.3353	0.7804
13	1.3363	0.7798
14	1.3361	0.7800
15	1.3361	0.7799
16	1.3351	0.7805
17	1.3365	0.7797
18	1.3364	0.7798
19	1.3373	0.7793
20	1.3373	0.7793
Average	1.3362	0.7799

**Table A8** Tabular data density analysis of PP of 1 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.3787	0.7458
2	1.3777	0.7463
3	1.3784	0.7459
4	1.3780	0.7461
5	1.3765	0.7470
6	1.3777	0.7463
7	1.3771	0.7467
8	1.3775	0.7464
9	1.3764	0.7470
10	1.3756	0.7475
11	1.3771	0.7466
12	1.3767	0.7469
13	1.3769	0.7468
14	1.3759	0.7473
15	1.3781	0.7461
16	1.3793	0.7454
17	1.3770	0.7467
18	1.3771	0.7466
19	1.3780	0.7461
20	1.3783	0.7460
<b>Average</b>	<b>1.3774</b>	<b>0.7465</b>

**Table A9** Tabular data density analysis of PP of 1.5 % ACA film

Run	Volume (cc)	Density (g/cc)
1	1.2818	0.7863
2	1.2796	0.7877
3	1.2814	0.7866
4	1.2826	0.7858
5	1.2799	0.7875
6	1.2854	0.7841
7	1.2843	0.7848
8	1.2871	0.7831
9	1.2884	0.7823
10	1.2868	0.7833
11	1.2850	0.7844
12	1.2842	0.7848
13	1.2816	0.7864
14	1.2812	0.7867
15	1.2828	0.7857
16	1.2847	0.7845
17	1.2840	0.7850
18	1.2840	0.7850
19	1.2830	0.7856
20	1.2823	0.7860
<b>Average</b>	<b>1.2833</b>	<b>0.7854</b>

### Appendix B Specific gravity of Dense and Voided Films by Density Kit

-Temperature of water: 21.7 °C

-Density of water: 0.99786 g/cm<sup>3</sup>

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	1.3455	1.3437	1.3413	1.3475	1.3515	1.3459	0.0039
Voided PVC, 14 wt% PVC	0.3246	0.3283	0.3264	0.3356	0.323	0.32758	0.0049
Voided PVC, 11 wt% PVC	0.2622	0.2678	0.2668	0.2639	0.2613	0.2644	0.0028

### Appendix C Data of Mechanical Properties of Dense and Voided Films

#### a) Flexural Test

Table C1 Flexural strength (MPa) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	22.57	22.92	23.21	22.73	22.02	22.69	0.44
Voided HDPE, 0.5% ACA	14.42	14.49	14.94	14.82	14.62	14.66	0.22
Voided HDPE, 1% ACA	13.71	13.43	13.51	13.80	13.82	13.65	0.18
Voided HDPE, 1.5% ACA	12.93	12.33	12.46	12.42	12.94	12.62	0.30
Voided HDPE, 2% ACA	11.32	10.9	11.59	10.88	11.58	11.25	0.35

Table C2 Flexural modulus (MPa) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	1081.00	1047.00	1085.00	1132.00	1061.00	1081.2	32.30
Voided HDPE, 0.5% ACA	557.50	566.40	560.70	565.10	551.20	560.18	6.14
Voided HDPE, 1% ACA	536.80	553.90	549.30	527.40	539.60	541.4	10.48
Voided HDPE, 1.5% ACA	493.80	490.10	506.30	494.40	490.10	494.94	6.66
Voided HDPE, 2% ACA	453.80	441.90	429.40	430.20	450.40	441.14	11.23

Table C3 Flexural strength (MPa) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PP	40.10	39.68	39.57	40.20	40.55	40.02	0.40
Voided PP, 0.5% ACA	19.99	22.38	21.43	21.72	21.38	21.38	0.87
Voided PP, 1% ACA	19.90	19.21	19.24	19.42	19.72	19.50	0.30

Table C4 Flexural modulus (MPa) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PP	1653.00	1626.00	1610.00	1651.00	1659.00	1639.80	20.90
Voided PP, 0.5% ACA	725.80	728.60	728.20	737.40	709.30	725.86	10.25
Voided PP, 1% ACA	691.90	636.80	646.10	645.10	659.30	655.84	21.71



### b) Tensile Test

Table C5 Young's modulus (MPa) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	401.44	360.46	377.48	370.46	393.67	380.70	16.76
Voided HDPE, 0.5% ACA	323.22	306.33	302.74	317.78	303.98	310.81	9.15
Voided HDPE, 1% ACA	301.82	295.40	297.89	303.21	302.27	300.11	3.33
Voided HDPE, 1.5% ACA	241.11	245.80	244.95	259.49	269.16	252.10	11.80
Voided HDPE, 2% ACA	236.17	223.22	224.35	234.76	211.14	225.93	10.14

Table C6 Tensile stress at break (MPa) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	2.17	2.11	2.27	2.11	2.22	2.18	0.07
Voided HDPE, 0.5% ACA	1.68	1.61	1.56	1.65	1.63	1.63	0.05
Voided HDPE, 1% ACA	1.56	1.54	1.48	1.52	1.48	1.52	0.03
Voided HDPE, 1.5% ACA	1.21	1.28	1.25	1.28	1.21	1.25	0.03
Voided HDPE, 2% ACA	1.03	1.11	1.10	1.11	1.17	1.10	0.05

Table C7 Percentage strain at break (%) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	248.36	272.89	236.86	262.63	272.89	258.73	15.83
Voided HDPE, 0.5% ACA	11.20	11.97	11.55	11.03	11.40	11.43	0.36
Voided HDPE, 1% ACA	13.24	13.97	12.61	13.23	13.16	13.24	0.48
Voided HDPE, 1.5% ACA	10.63	10.99	10.19	10.96	10.78	10.71	0.32
Voided HDPE, 2% ACA	8.72	8.00	8.17	7.99	8.52	8.28	0.32

Table C8 Young's modulus (MPa) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PP	380.34	411.25	383.04	395.95	378.43	389.80	13.80
Voided PP, 0.5% ACA	335.23	321.54	336.58	316.26	328.12	327.55	8.73
Voided PP, 1% ACA	309.02	314.5	324.74	310.3	312.9	314.29	6.22

Table C9 Tensile stress at break (MPa) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PP	2.60	2.62	2.74	2.72	2.64	2.66	0.06
Voided PP, 0.5% ACA	1.59	1.46	1.43	1.48	1.47	1.49	0.06
Voided PP, 1% ACA	1.57	1.56	1.56	1.66	1.76	1.62	0.09

Table C10 Percentage strain at break (%) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	1.3455	1.3437	1.3413	1.3475	1.3515	1.3459	0.0039
Voided PVC, 14 wt% PVC	0.3246	0.3283	0.3264	0.3356	0.323	0.32758	0.0049
Voided PVC, 11 wt% PVC	0.2622	0.2678	0.2668	0.2639	0.2613	0.2644	0.0028

Table C11 Young's modulus (MPa) of PVC at various polymer concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	1018.10	1222.59	1032.24	1014.72	1103.46	1078.22	88.37
Voided PVC, 14 wt% PVC	224.86	213.19	223.24	209.73	225.44	219.29	7.30
Voided PVC, 11 wt% PVC	140.78	143.74	125.01	134.04	125.30	133.77	8.62

Table C12 Tensile stress at break (MPa) of PVC at various polymer concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	2.93	3.30	3.38	3.13	3.14	3.18	0.17
Voided PVC, 14 wt% PVC	0.74	0.74	0.70	0.72	0.65	0.71	0.04
Voided PVC, 11 wt% PVC	0.34	0.40	0.36	0.42	0.43	0.39	0.04

Table C13 Percentage strain at break (%) of PVC at various polymer concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	394.82	412.58	426.06	421.26	415.13	413.97	11.93
Voided PVC, 14 wt% PVC	17.72	17.00	17.00	17.21	17.05	17.20	0.31
Voided PVC, 11 wt% PVC	6.29	5.89	5.72	5.88	6.22	6.00	0.24

### Appendix D Data of Dielectric Strengths of Dense and Voided Films

Table D1 Dielectric strength (MV/m) of HDPE with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense HDPE	10.56	10.12	9.65	10.37	9.48	10.04	0.46
Voided HDPE, 0.5% ACA	9.85	9.55	9.58	9.14	9.12	9.45	0.31
Voided HDPE, 1% ACA	8.85	8.21	7.95	8.34	7.90	8.25	0.38
Voided HDPE, 1.5% ACA	6.99	7.11	6.51	6.51	6.62	6.75	0.28
Voided HDPE, 2% ACA	5.59	5.38	5.64	6.12	6.18	5.78	0.35

Table D2 Dielectric strength (MV/m) of PP with various ACA concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PP	11.06	11.33	11.04	11.16	11.15	11.15	0.11
Voided PP, 0.5% ACA	6.53	6.96	7.17	6.79	7.32	6.96	0.31
Voided PP, 1% ACA	5.61	5.44	5.08	5.18	5.47	5.36	0.22

Table D3 Dielectric strength (MV/m) of PVC at various polymer concentrations

Sample	1	2	3	4	5	AV.	SD.
Dense PVC	18.22	17.90	17.52	18.19	18.13	0.29	17.99
Voided PVC, 14 wt% PVC	4.51	4.75	5.00	4.81	4.62	0.19	4.74
Voided PVC, 11 wt% PVC	4.45	4.34	4.46	4.27	4.18	0.12	4.34

## CURRICULUM VITAE

**Name:** Ms. Weerawan Weeramethachai

**Date of Birth:** April 30, 1983

**Nationality:** Thai

**University Education:**

2001-2005 Bachelor Degree of Food Technology, Faculty of Science, Chulalongkorn University, Bangkok, Thailand

**Proceedings:**

1. Weeramethachai, W; Manuspiya, H; and Bhalla, A.S. (2010, March 21-25) Enhanced Dielectric Properties of Non-Polar Polymers by Internal Pores. Proceedings of 239<sup>th</sup> American Chemical Society Spring 2010 National Meeting & Exposition, San Francisco, California, United State of America.
2. Weeramethachai, W; Manuspiya, H; and Bhalla, A.S. (2010, April 22) Induced Dipole in Non-polar Polymers by Charges Trapping Surface. Proceedings of the 16<sup>th</sup> PPC Symposium on Petroleum, Petrochems, and Polymers, Bangkok, Thailand.

**Presentations:**

1. Weeramethachai, W; Manuspiya, H; and Bhalla, A.S. (2010, March 21-25) Enhanced Dielectric Properties of Non-Polar Polymers by Internal Pores. Paper presented at the 239<sup>th</sup> American Chemical Society Spring 2010 National Meeting & Exposition, San Francisco, California, United State of America.
2. Weeramethachai, W; Manuspiya, H; and Bhalla, A.S. (2010, April 22) Induced Dipole in Non-polar Polymers by Charges Trapping Surface. Paper presented at the 16<sup>th</sup> PPC Symposium on Petroleum, Petrochems, and Polymers, Bangkok, Thailand.

